Appendix E – Economic and Business Supporting Documents

- Highway 53 Relocation Economic Impact Study – Summary of Findings (McComb Group and SEH, 2014)
- Structural Cost Estimate for Elevated Tunnel for US 53 Alternative M-1 Air Quality Mitigation (Kimley-Horn, 2013)
- Highway 53 M-1 Alignment Air Quality Mitigation Assessment (CH2M Hill, 2013)

HIGHWAY 53 RELOCATION ECONOMIC IMPACT STUDY

Prepared for

Minnesota Department of Transportation

Prepared by

McCOMB GROUP, Ltd.
REAL ESTATE AND RETAIL CONSULTANTS

SEH

January 2014

SUMMARY OF FINDINGS

Economic impacts of relocating Highway 53 from its current location to Alternative W-1A were evaluated by McComb Group, Ltd. and Short Elliott Hendrickson, Inc. (SEH). The three other alternatives under consideration (M-1, E-1A, and E-2) were not evaluated as part of this economic analysis because the differences in travel distance and time as compared to the existing route are negligible from an economic impact standpoint. Economic impacts quantified in this report include significant economic and government service categories, but do not include all of the economic impacts that businesses, residents, and visitors to the area would experience. As such, they represent a snapshot of economic and service impacts, but are not all inclusive of all economic impacts that would result from Alternative W-1A. In addition, there are numerous quality of life impacts that, by their very nature, are difficult to identify and quantify.

Highway 53 is a north/south route extending from International Falls on the north to Duluth/Superior and south into Wisconsin. The area between Virginia and Eveleth is also the route for Highway 135, an east/west route connecting the East Iron Range area to Virginia, Mountain Iron, and cities to the north and west. These two highways cross the Biwabik Iron Formation, which flows through the area similar to a river with Highway 53 being a major “river crossing” between Buhl to the west and Aurora to the east.

The study area has the greater Virginia area as its core and extends generally from Hibbing on the west to Hoyt Lakes and Babbitt on the east, and the areas north and south of the Biwabik Iron Formation. The greater Virginia area including Mountain Iron, Eveleth, and Gilbert is known as the Quad Cities. Virginia serves as the shopping, cultural, social, and governmental center for the East Range area. The Quad Cities are separated by the Biwabik Iron Formation--Virginia and Mountain Iron on the west and the Midway portion of Virginia, Eveleth, and Gilbert on the east.

This report assumes that a new route for Highway 53 will be operational for a full year in 2017. Economic impacts are calculated through 2037. Economic impacts are divided into two time periods. The first time period is 2017-2023, when it is assumed that County Road 101, a connection between Highway 7 and Highway 53 through Eveleth (County Road 101), will be operational and provide an alternative shorter route to Alternative W-1A. This road is assumed to be closed by mining operations by 2024 making the Alternative W-1A the only available route. Economic impacts for motorists using County Road 101 during the 2017-2023 period will be lower. The full economic impacts will occur for the 2024-2037 period of the analysis. Economic impacts quantified in this report are summarized below.

User Costs

Cost benefit analysis determined that Alternative W-1A would result in increased user costs between 2017 and 2037 of $765.4 million, discounted at 2.2 percent to 2013. Increased annual user costs for 2017 were estimated at $32.0 million, which discounts to $29.9 million in 2013. In 2024, increased user costs were estimated at $43.4 million, which discounts to $34.2 million in 2013.

Commuter Costs

Work locations of study area employed residents were analyzed for 2011 and determined that about 5,500 workers that would experience increased travel times as a result of Alternative W-1A. These commuters are expected to total about 6,000 in 2017, 6,900 in 2024, and 8,600 in 2037. The total value of commuter user costs for the period 2017 to 2037 is $449.2 million. The discounted value is $323.8 million in 2013 dollars. These commuters are included in the cost benefit analysis described above, but demonstrate how Alternative W-1A affects one user group.

The annual impact on individual commuters represents a significant portion of their income. Workers living or working in East Range cities (Eveleth, Gilbert, McKinley, Biwabik, Aurora, and Hoyt Lakes) and commuting over the current Highway 53 route will drive an additional 7,650 miles annually and spend an additional 152 hours commuting with Alternative W-1A. Annual travel and time costs for each employee are estimated at $4,653. This is about $18.61 per day or $2.33 per hour. Annual increased commuting costs of this magnitude will cause workers to consider changing either their home or work location.

Retail Impacts

Virginia, Mountain Iron, and Eveleth contain the Quad Cities' largest concentration of retail stores and services. The largest retail concentration is Virginia and the eastern portion of Mountain Iron. Virginia/Mountain Iron retail sales in 2017 are estimated at $560.9 million in 2013 dollars. Market research found that 33 percent of these sales or $183.7 million were derived from customers living in the East Range area. The longer drive time associated with a shopping trip to Virginia/Mountain Iron resulting from the Alternative W-1A route was estimated to result in a sales transfer of $41.7 million or 7.4 percent of total sales in the 2017-2023 period.

In 2024, retail sales are expected to be about $645 million (in 2013 dollars) with $211 million derived from shoppers residing in the East Range area. Of this amount, $95 million, or 14.7 percent of total sales are estimated to be transferred to retail stores in other locations. Most of these sales will transfer to Duluth and Hermantown, which have much larger retail areas and offer greater selection. Some convenience goods and service spending will transfer to businesses in East Range cities.

Employment in retail establishments is closely related to sales volume. Reduced retail sales in Virginia are estimated to result in a loss of 372 jobs in the 2017-2023 period increasing to 844 jobs after 2024.

Eveleth retailers are also affected by sales transfer resulting from Alternative W-1A. Market research found that 34 percent of Eveleth retail sales are derived from customers living in Virginia and cities to the west and north. Eveleth's retail sales are estimated at $87.2 million in 2017 with $29.9 million derived from shoppers living to the west and north. Retail sales transfer resulting from Alternative W-1A is estimated at $9.2 million or 10.5 percent of retail sales.

Retail sales transfer increases in 2024 resulting from closing County Road 101. In that year, retail sales are estimated at $100.1 million with $34.3 million derived from shoppers living west and north of the Biwabik Iron Formation. Sales transfer is estimated at $20.1 million of estimated 2024 retail sales.

Reduced retail sales at Eveleth retail establishments will result in the loss of an estimated 76 jobs in the 2017-2023 period, increasing to 154 jobs in the 2024-2037 period.

Business Impacts

Businesses in the study area make deliveries or service calls to customers living on either side of the Biwabik Iron Formation resulting in frequent trips over Highway 53. Market research based on business survey responses estimated increased travel and payroll cost to local businesses of $45.9 million in the 2017-2023 period, increasing to $97.0 million annually in the 2024-2037 period. Businesses in the survey reported higher operating and time costs than utilized in the user cost analysis.

Sixty-four business survey respondents identified 124 companies that made a total of 787 deliveries per week. This is an average of 12.3 deliveries per week for each business. Many of these deliveries include distributors of food, beverages, and other consumer products that are from cities outside the Iron Range area.

Lodging and Attractions

The Virginia/Mountain Iron lodging industry has stronger operating characteristics than the Eveleth/Midway area. Occupied room nights, occupancy rate, and the average daily room rate are all higher. Operating characteristics of the three properties in the Eveleth/Midway area indicate a lodging industry that is characterized by lower occupied room nights, occupancy rate, and average daily room rate.

The cumulative impacts of shifts in traffic flow and accessibility for lodging properties in Eveleth/Midway resulting from Alternative W-1A will have severe impacts on occupancy and room rates at these properties. The negative impacts associated with Alternative W-1A for Eveleth/Midway properties include:

- ♦ Reduced traffic counts on Highway 53 that will eliminate almost all of the drive-by traffic.
- ♦ Severing the convenient connection between Virginia and Eveleth/Midway will reduce the area’s attraction to business guests, as many of the businesses are located in Virginia and areas to the west.
- ♦ Tourist occupancy is expected to decline due to reduced access and convenience to the Virginia area.

The combination of these three factors will cause the eventual closing of all three lodging properties in Eveleth/Midway.

The Hockey Hall of Fame in Eveleth is dependant on the tourism traffic on Highway 53 and is, according to hotel survey respondents, responsible for about 825 room nights at local lodging establishments. The loss of drive-by visitor traffic will result in significant decline in attendance at the Hockey Hall of Fame and could result in it closing.

Workforce Aging

The East Range area had 7,021 employed workers in 2011. Between 2012 and 2037, over 4,000 of these workers will reach retirement age. About 1,400 of these workers (36 percent) commute to jobs in Virginia and areas to the west and north. Jobs held by these retiring workers will be filled by new workers. Alternative W-1A and its longer drive time are likely to influence where these replacement workers will live. The result will be reduced demand for housing and fewer customers for local businesses in East Range cities.

Real Estate Impacts

Realtors commented that Alternative W-1A would reduce the demand for housing in the East Range cities and anticipated it would cause a 10 percent decrease in market values. Commercial and industrial real estate demand would also be affected. However, due to the current high vacancy rate, the impact would be less.

Development Impacts

The additional travel times between East and West Range areas for work, shopping, and other household travel resulting from Alternative W-1A will influence household choices on where to live on the part of existing residents and potential new residents. Study area employment was estimated to increase by about 10,950 between 2017 and 2037. Adding the impact of employee retirements increases potential new employees to about 15,000 between 2017 and 2037.

Residential areas in Virginia and other West Range cities will have a competitive edge in attracting new residential development created by increased employment. These same forces will reduce the demand for resale of existing homes in East Range communities.

Private Sector Summary

Increased travel and time costs associated with Alternative W-1A will have broad economic impacts on residents, businesses, and visitors to the area. Many of the impacts will be reflected in diminished lifestyle for those traveling east/west across the Biwabik Iron Formation. Private sector economic impacts associated with Alternative W-1A over the period 2017-2023 were calculated two ways: 20-year discounted value of user costs and annual increased costs for representative years of 2017 and 2024.

Twenty-year present value of user costs was estimated at $765 million. The portion of this cost associated with worker commuting was estimated at over $323 million.

Annual economic impacts associated with Alternative W-1A are summarized in Table i for 2017-2023 and 2024-2037.

Table i

INCREASED ANNUAL COSTS
SELECTED IMPACT CATEGORIES

Impact Category	2017-23	2024-37
Employee Commuting Costs	$ 13,256,060	$ 22,292,756
Business Increased Travel Costs	45,904,447	97,043,447
Toal	59,160,507	119,336,203
Virginia Lost Retail Sales	41,657,000	94,845,000
Eveleth Lost Retail Sales	9,193,000	20,116,000
Total	$ 50,850,000	$ 114,961,000
Lost Retail Jobs		
Virginia	372	843
Eveleth	76	154
Total	448	997

Source: McComb Group, Ltd.

Annual private sector costs for employee commuting and business travel costs total $59.2 million in 2017 increasing to $119.3 million annually in 2024. Retail sales transfer was estimated at $50.8 million in 2017 and $115.0 million in 2024. Total long-term annual economic impacts for only these categories are estimated at over $234 million, not including the lost wages for about 1,000 retail workers.

Foreseeable additional impacts in East Range communities resulting from the longer distance and travel times associated with Alternative W-1A include:

- Employees living in Virginia and areas west and north will experience higher commuting costs.
- Employers will experience difficulty in retaining and attracting workers from Virginia and areas west and north.
- Convenience retail and services will experience short-term increase in business until declining population reduces demand.
- Businesses will experience higher costs to serve customers in Virginia and areas west and north.
- Reduced demand for housing and lower prices for existing homes.
- Higher commuting costs may cause workers to seek jobs closer to home.
- Increased travel costs for work, shopping, and other trips will reduce income for other household purchases.
- Residents and businesses that use St. Louis County services will experience longer travel times to government offices.

- St. Louis County will experience higher costs to provide services in the East Range area.

Retail stores and services in East Range cities are primarily convenience businesses that serve a local market. These businesses may experience increased sales as competitors in Virginia become more distant and are less convenient to visit. Eventually, sales for these businesses will decline as population declines due to the higher travel costs and time required to reach the Virginia area for shopping, social, and recreational activities, and government services. If these sales declines result in businesses closing, the area becomes less attractive to residents.

These are but a few of the economic and social impacts of Alternative W-1A on residents, businesses, and other entities in East Range cities.

Public Sector Impacts

Eliminating the current Highway 53 route between Virginia and the East Range cities will have significant impacts on emergency services, educational institutions, cities, and other agencies.

Residents living in seven cities, together with surrounding rural areas, depend upon shared services making travel among communities frequent and necessary. Shared services include: ambulance, police, fire, education k-12, special education, a two campus community and technical college, St. Louis County Social Services, and economic development agencies, to name just a few.

The Alternative W-1A route will add a minimum of 20 minutes one way, in addition to the time it already takes, to emergency response times; lengthening the Golden Hour (the time period when prompt medical treatment will prevent death). Also, Virginia is the only town equipped with access to an emergency helipad and has the only Advanced Life Support unit in the area.

Essentia Health is in the process of investing millions into the facilities in Virginia to make it a regional secondary hub to Duluth for regular and emergency health services.

The sheriff's office, jail, and court house are located in Virginia. Increase travel times limits access to and from area communities.

Area fire and police departments have entered into mutual aid agreements whereby they support one another. Virginia owns the only ladder truck for fire safety and rescue.

Local schools (pre-school- 12) transport children among the various communities as part of open enrollment and transport children as part of shared services and classes. Increased travel time puts the students and the services at risk.

Mesabi Range Community and Technical College has two campuses (Virginia and Eveleth). College students and high school students from their home schools travel between the campuses to take advantage of the course work available. Increased travel time puts the programming and students at risk.

Services provided by Northeast Special Education Co-op, Arrowhead Economic Opportunity Agency, and Range Mental Health Center - serving children and adults spread across the area communities will be affected. Increased travel time inhibits the ability for these services to reach out to area communities.

Local governments, schools, and other agencies identified the additional annual operating costs and capital expenditures that would result from the Alternative W-1A route. These costs are summarized in Table ii. Increased annual costs total $4.3 million and capital costs are estimated at $24.5 million.

Table ii

INCREASED ANNUAL EXPENSES AND CAPITAL EXPENDITURES RESULTING FROM ALTERNATIVE W-1A

	Annual Cost	Capital Expenditures
Virginia		
Public Works		$ 475,000
Utility Relocation		20,000,000
Police Department	480,000	
Fire Department	1,560,000	3,740,000
Park and Recreation		260,000
Public Schools	1,607,100	
Subtotal	$ 3,647,100	$ 24,475,000
Eveleth		
Public Works	$ 16,400	
Tri Cities	11,800	
Subtotal	$ 28,200	
Eveleth-Gilbert Public Schools		
Transportation Costs	$ 66,000	
Arrowhead Transit	$ 554,882	
Total	$ 4,296,182	$ 24,475,000

Source: SEH.

Arrowhead Transit provided cost estimates indicating that in the 2017-2023 period, it would experience increased operating costs in 2013 dollars of $370,000 per year and $554,000 over the longer term after 2023.

Alternative W-1A will impose the highest cost increase on Virginia; while the emergency response impacts will fall on East Range cities and their residents, employees, and businesses.

Kimley-Horn and Associates, Inc.

Technical Memorandum

Suite 238N
2550 University Avenue West
St. Paul, Minnesota
55114

Date: November 13, 2013

To: Roberta Dwyer, MnDOT

From: Jerry Schwientek, P.E., and Beth Kunkel

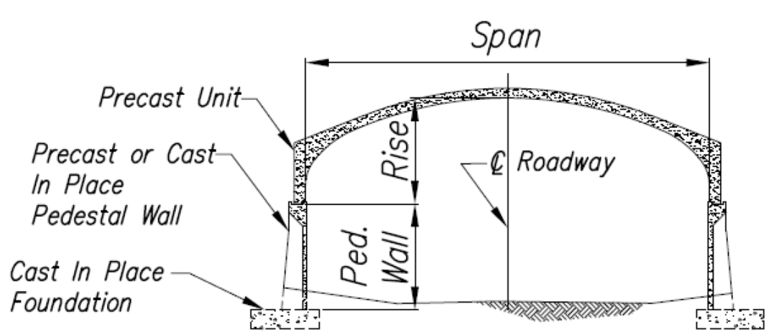
Subject: **Structural Cost Estimate for Elevated Tunnel for US 53 Alternative M-1 Air Quality Mitigation**

As part of our evaluation of options to provide a physical barrier/cover over US 53 through the mine on the M-1 alignment, several options were considered. All but one of these options were ultimately deemed unsuitable due to concerns with constructability, loading capacity, durability, maintenance, and/or costs.

Options considered included:

1) Cast-in-Place tunnel
2) Steel framed structure
3) Prefabricated buildings
4) Fabric structures, such as for Agricultural use
5) Precast 3-sided structure

Considering these options, it was determined the most appropriate option for further evaluation was a 3-sided precast structure on pedestal walls as shown below. This proposed structure type will meet the durability requirement of a structure expected to have a 75 year or greater service life, provide protection from expected mining activities, provide crash resistant walls, support snow and wind loads, and require minimal annual maintenance.



To develop a cost estimate for purposes of evaluating this tunnel option, a precast 3-sided structure on pedestal walls with spread foundations was assumed, with a separating wall at the median. To accommodate the air/fire ventilation equipment, a 30-foot section every 250 feet was included to provide the additional required vertical clearance. The dimensions of this proposed structure are as identified in the following table.

Tunnel Width	Vertical Clearance	Cross Section
(2) 36'-0" Tunnels	17'-4" (24'-0' at ventilation equipment)	(2) 12'-0" lanes and an 8'-0" Shoulder each direction

The approximate planning level unit cost for a 3-sided structure of this type was $165/sq.ft. (which includes $80/sq. ft. for the precast and $85/sq. ft. for the pedestal walls). Since the pedestal walls can be designed for a vehicular impact load, additional barriers on the inside of the tunnel will not be required. Structural costs for the two tunnel lengths are summarized below.

3,000 foot length	6,100 foot length
$35,640,000	$72,470,000

Other items that would be required as part of the structural cost estimate include: fire protection (hydrant hook ups), sanitary sewer collection from tunnel, storm sewer, and tunnel lighting. Approximate costs for those are summarized below for the two tunnel sizes.

	3,000 foot length	6,100 foot length
Fire Protection	$270,000	$550,000
Sanitary Sewer	$255,000	$520,000
Storm Sewer	$240,000	$490,000
Lighting	$240,000	$490,000

Cost summary of the above noted items is as follows:

3,000 foot length	**6,100 foot length**
$36,645,000	**$74,520,000**

These costs are based on general assumptions for constructing a 3-sided tunnel structure as described above. This estimate specifically does **not** include:

1) Cost for the bridge structures
2) Bridge upgrade costs to support the 3-sided structure, if needed
3) Deep foundations if needed for pedestal walls
4) Access doors, emergency exits
5) Ventilation system (see Air Quality Mitigation Memo)
6) Traffic management camera system
7) Unique loading conditions
8) Roadway items – Mass grading, roadway pavements
9) Utility connections to tunnel
10) Contingency
11) Other items not noted above

Highway 53 M-1 Alignment Air Quality Mitigation Assessment

PREPARED FOR: Roberta Dwyer/MnDOT

PREPARED BY: Evan Cobb/CH2M HILL, Carrie MacDougall/CH2M HILL, Don Caniparoli/CH2M HILL, and Baljinder Bassi/CH2M HILL

DATE: November 12, 2013 (Revised 12-09-13)

1.1 Background

The purpose of this technical memorandum is to assess the feasibility of air quality mitigation measures on the M-1 alternative currently under consideration by the Minnesota Department of Transportation (MnDOT) as part of the Highway 53 Draft Environmental Impact Statement (DEIS) between Virginia and Eveleth. The proposed M-1 route travels through the Cliffs Natural Resources (Cliffs) operated United Taconite mine. As proposed, this route would potentially have mine operations occurring on either side of the highway. There are few instances of a highway passing through an operating mine and thus limited precedent for evaluating resulting business air quality standards compliance issues in such a situation. A concern of this alternative is the potential for exposing the public (travelers on Highway 53) to air that exceeds federal National Ambient Air Quality Standards (NAAQS) for a portion of the highway corridor through the mine.

1.2 Objective and Air Quality Regulatory Factors

The objective of this memo is to evaluate options for air quality mitigation that could be implemented by MnDOT on the M-1 route to mitigate the potential NAAQS exposure issues. It is not intended to evaluate or suggest air quality mitigation measures that could be implemented by Cliffs.

Key considerations for the analysis of MnDOT's options for mitigation on M-1 include:

- Right-of-way requirements – because the roadway would be running in an elevated position relative to the operating mine, any widening of the highway cross-section would have consequences on the overall project footprint in the mine. As the footprint gets wider, the extent of iron ore that is sequestered (no longer accessible to the mine) is likely to increase as well.
- Vertical profile – Highway 53 enters Virginia from the south on a down-gradient slope. Any measures that elevate the road profile would create safety and access issues for entry to south side of Virginia, where a commercial business district and the Riverwood neighborhood are provided access to the highway. Raising the highway could cause the elimination or re-routing of access points.

The purpose of this technical memo is to evaluate mitigation options that may allow receptors on US 53 to be within a M-1 alternative corridor that meets ambient air quality standards. One mitigation option is to enclose a segment of proposed Highway 53 in a tunnel or tube (hereafter referred to as an "elevated tunnel"), thereby separating US 53 travelers (receptors) from higher levels of particulate matter generated by mining activities. The following information serves as an analysis of the feasibility issues associated with such a mitigation option.

1.2.1 Mine Air Quality Permitting

Based on an air quality modeling culpability analysis performed by Cliffs, their results indicated a potential for exceedance of the 24-hour National Ambient Air Quality Standard (NAAQS) for particulate matter 10 micrometers in size or smaller (PM_{10}) in the M-1 route scenario. The mine's air quality model has shown that this standard would not be met on the northerly segment of the proposed M-1 alignment. This northern area is most susceptible to PM_{10} concerns because it is closer to dust generating activities in and around the mine.

The modelling analysis conducted by Cliffs Natural Resources indicated a potential for the exceedance of the 24-hour PM10 standard of 150 micrograms per cubic meter ($\mu g/m^{3)}$. According to a December 2012 memorandum entitled *Consideration of Mitigation Options,* the modelling analysis indicated the potential for a NAAQS exceedance at two modelled receptor locations at 24-hour averaged PM_{10} concentrations of up to 200 $\mu g/m^3$. These results demonstrate how introducing the M-1 alternative within the United Taconite mine may affect the mine's ability to meet NAAQS for future permitting.

1.2.2 Additional Regulatory Conditions

1.2.2.1 Background Air Quality

The area is classified as attainment for all NAAQS standards, as the surrounding environment is characterized by air quality that is in compliance with national standards. No other air quality issues are anticipated for this project.

1.2.2.2 Mobile Source Air Toxics

Mobile Source Air Toxics (MSAT) assessments are required for most federal transportation projects. Based on the example projects defined in the FHWA guidance *Interim Guidance Update on Mobile Source Air Toxic Analysis in NEPA* dated December 6, 2012, Highway 53 would be classified as a project with Low Potential MSAT Effects.

1.2.2.3 Traffic Analysis

The projected average daily traffic volumes of 28,650 vehicles are assumed to not be affected by any of the mitigation alternatives evaluated. Carbon monoxide levels are not a concern at the forecasted traffic volumes for this project; therefore, air quality mitigation discussions will not consider pollution from vehicle traffic.

A potential outcome of mitigation analysis is to recommend restrictions on the types of vehicles allowed to travel on the proposed Highway 53 segment. A restriction on vehicles that carry hazardous materials (re-routing vehicles to an alternative roadway) could be implemented with substantial reduction to the cost of mitigation. By eliminating the potential presence of hazardous materials in the tunnel reduces the design fire size, and as a result reduces the scope and cost of implementing emergency air ventilation equipment. Such a restriction is assumed to have a negligible effect on traffic volumes on this segment of Highway 53.

1.2.2.4 National Ambient Air Quality Standards

Potential exists for an exceedance of the 24-hr PM_{10} standard due to nearby mining activity. As this tech memo demonstrates, further analyses are required to determine if an elevated tunnel could adequately protect the road surface from the elevated PM_{10} levels.

1.3 Mitigation Design Considerations

In order to successfully mitigate the high levels of PM_{10} on the roadway to below the NAAQS, the PM_{10} loading must be reduced by approximately 25%. Analysis of standard management practices at the mine indicate that current efforts at the mine appear to be fully leveraged; therefore, further reduction of PM_{10} by way of modified mine practices does not appear to be a viable option for achieving the target reduction.

As described above, the proposed M-1 route is subject to a unique environment with substantial limitations to the design and space that it can occupy in the mine. The intent of any proposed mitigation is to prevent ambient air conditions at the roadway to exceed the threshold for PM_{10}.

In response to these constraints, the primary method available to make the M-1 route feasible is to create a barrier along the roadway that reduces exposure to particulate matter or creates an environment where the air can be treated to levels below the standard for PM_{10}.

Details of the Cliffs modelling analysis have not been made available to MnDOT for review. Based on Cliffs' presentation of results from their culpability analysis, there is one portion of the M-1 route that is clearly at risk for exceeding the NAAQS threshold (shown with red dots in Figure 1 of the December 2012 memo). There are also portions at either end of the M-1 route that are not at risk for exceeding the PM_{10} threshold (shown with blue dots in Figure 1).

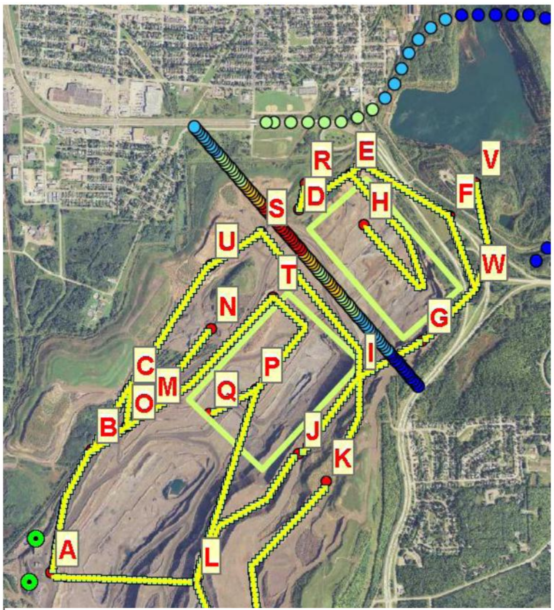


Exhibit 1: Culpability Analysis from Cliffs (December 2012)

1.3.1 Mitigation Options

Since a reduction in PM_{10} emissions from a change in mine practices is not a viable mitigation option, only a combination of physical barriers and air filtration equipment were considered. Multiple mitigation options were considered for the proposed route M-1:

- Elevated Tunnel
  - An elevated tunnel spanning the entire length of the permit-to-mine area. Air filtration equipment may not be required.
  - An elevated tunnel spanning only the permit-to-mine area with the highest PM_{10} concentrations. Air filtration equipment would likely be required.
- Depressed Roadway
  - A elevated roadway with walls approximately 20' in height could potentially reduce exposure to elevated PM_{10} concentrations. The elevated roadway could be shielded from external PM_{10} sources and create a "depressed roadway". Air filtration equipment would not be feasible.

- Non-structural Coverings
  - An elevated roadway with non-structural coverings (flexible “tarp” shields) above the roadway could potentially reduce exposure to elevated PM_{10} concentrations. Air filtration equipment would not be feasible.

The elevated tunnel mitigation options would involve significant engineering and construction costs as discussed later in this memo; however, the technology used to reduce elevated PM_{10} levels have been demonstrated as a common and effective technology in transportation projects. The two elevated tunnel lengths as mitigation options contain the least amount of uncertainty and are the focus of this mitigation assessment. The two mitigation options involving an elevated tunnel are referenced as Option 1 and 2 for the remainder of this mitigation assessment.

The depressed roadway mitigation option would involve a formal air quality dispersion modeling effort to determine the effectiveness of the heightened walls to shield the elevated roadway from high PM_{10} concentrations. In addition, the walls would create a depressed roadway that would trigger fire protection safety standards similar to those required in tunnels. Considering depressed roadways require similar fire safety requirements as tunnels and that any improvements in air quality along the roadway are unknown, the wall mitigation concept is likely infeasible and not addressed further in this memo.

Non-structural coverings over the elevated roadway were discussed as a means of providing a physical barrier at a reduced cost; however, non-structural elements were deemed an unorthodox solution with potential safety issues. This mitigation option is not addressed further in this memo.

1.3.2 Tunnel Dimensions and Highway Characteristics

The M-1 alignment through the United Taconite Mine as described in the EIS would be a four-lane highway consisting of two travel lanes in each direction with traffic volumes projected to be approximately 28,650 vehicles per day. The tunnel would be divided by a central wall to create two tunnel sections with two travel lanes in each side of the tunnel. Typical cross sections indicate the two tunnel sections would be approximately 37’ wide including the travel lanes, median, shoulders, and emergency egress access. There are no intersecting access points within the boundaries of the mine, and no access is possible except from either end of the highway outside the mine limits. The road surface would vary in height from 50 to 100 feet above the current mine surface.

An example of how fire protection requirements affect tunnel design is in how egress must be available in the event of a fire inside the tunnel. If the tunnel were designed as one portal opening containing the entire cross-section, provision of emergency egress to an exterior walkway would be necessary. However, by placing a dividing wall at the median with fire doors at regular intervals, the emergency egress would be created by providing two separate tubes, one for each direction of travel. Such a measure is assumed for this scenario, as it helps maintain a smaller cross-section and project footprint in the mine.

The tunnel height and width have been determined by various sources cited in the table below; however, two different tunnel lengths are being considered for the air quality mitigation analysis. The table below presents the dimensions of the tunnel for the proposed route as currently known. For planning purposes, the permit to mine length has been assumed. Per the dimensions listed in NFPA 502 (see Attachment B), the range of tunnel lengths available place the tunnel either in the Category “C” or “D” classification (see Table 2).

TABLE 1 – APPROXIMATE M-1 ROUTE M-1 TUNNEL DIMENSIONS

Characteristic	Total/Component	Tunnel Dimension	Source
Height	Total	Standard tunnel section: 17'4" Fan niche section: 24' = 17'4" + ~6' (two fan diameter lengths@ 3' diameter)	Assumption based on providing no less than MnDOT standard 17'4" vehicle clearance in standard tunnel section and approximately 6' in additional height in niche sections housing tunnel fans and associated equipment.
Width	Total	2 tunnels at 37' wide each	Assumption based on four lanes of traffic (12' per lane) and shoulder/emergency egress widths.
Length	Option 1	6,100' or 1.15 miles(s)	Full permit-to-mine area from MnDOT (SEH) PDF drawing of road profile: *air quality – profile.PDF*
	Option 2	3,000' or 0.55 mile(s)	Approximation of diagram for coverage of key area, from: *Dec 2012 Consideration of Mitigation Options.PDF* from Cliffs Natural Resources

If the entire permit-to-mine area is spanned by the proposed route, the tunnel will cross over two bridges that handle mining vehicles. As discussed previously, it is proposed that a tunnel along the proposed route M-1 would mitigate the high levels of PM_{10} on the roadway. The proposed route is in a constrained right-of-way area, so any air handling and filtration equipment that may be needed cannot be located adjacent to the roadway as it is desirable to keep the roadway footprint as narrow as possible. Even so, the construction of a tunnel structure is likely to require additional features (such as barriers or foundations) that result in a wider footprint needed than described above. Some of these features may potentially have no impact on the horizontal footprint of the project. Closer analysis of the space requirements would be necessary during more detailed design.

1.3.3 Tunnel Air Management

1.3.3.1 Air Treatment

With the air environment as depicted in Exhibit 1, there are two basic treatment options for meeting the air quality mitigation objective with a tunnel concept:

1) **Option 1** – This tunnel length (6,100') covers the entire permit-to-mine area. The tunnel portals would be located outside the area of elevated PM_{10} concentrations, and it assumed that air entering the tunnels would meet all NAAQS standards. As such, the requirements for air treatment equipment were eliminated.

2) **Option 2** – This tunnel length (3,000') would cover the area of elevated PM_{10} concentrations, but the tunnel portals would still be exposed to elevated PM_{10} levels. This option would require the installation of an air treatment system capable of reducing the PM_{10} concentrations below the NAAQS standards. This option relies on air treatment equipment and assumes that the area at risk will not shift due to changes in mine operations and practices or due to changes in the air quality standard for PM_{10}.

In summary, a longer tunnel (Option 1) covering the entire permit-to-mine area would likely not require air filtration equipment that would be needed on the shorter tunnel (Option 2)

1.3.3.2 Tunnel Ventilation

Ventilation of air through the tunnel would generally be achieved through placement of jet fans inside the tunnel (see Exhibit 2 for a representative tunnel fan arrangement). The presence of jet fans are a requirement of fire protection standards (see Section 1.3.4 below) and for the purposes of this analysis are not considered part of the air quality mitigation strategy for either Option 1 or Option 2. For Option 2, the use of fans ventilating the tunnel can help dilute tunnel air; however, the effects of jet fans on the air filtration equipment were not considered in the cost analysis. For Option 1, the source air is below the threshold and PM_{10} levels are not expected to be an issue within the tunnel.[1]

Ventilation would still be a necessary component of any tunnel longer than 1,000 feet in order to respond to potential emergency situations. Carbon monoxide and NO_X are also potential concerns of any tunnel environment. Modeling of the tunnel based on the US EPA MOVES analysis methodology would also be required. For the probable tunnel lengths involved in this project, ventilation is likely to be necessary.

1.3.3.3 Fire Safety

Fire protection standards for tunnels are provided by National Fire Protection Association (NFPA) standard 502. Tunnel length dictates the minimum fire protection standards. Tunnels greater than 3,280 feet (Category “D” tunnels) have the most restrictive standards. Tunnels between 1,000 feet and 3,280 feet long (Category “C”), are subject to nearly the same standards, with some minor differences (see Exhibit 3 at the back of this memo for a summary of the fire protection standards in both categories). Based on the modeling results as depicted in Exhibit 1, the shortest reasonable tunnel length to address the mitigation requirements for the M-1 route is expected to be no less than 1,000 feet.

Exhibit 2. Example jet fan arrangement for air ventilation

Potential tunnel safety requirements include fire detection systems, communication systems, traffic control systems, fire protection systems, means of emergency egress from the tunnel, electrical systems, and the creation of an emergency response plan. These items are not related to improving air quality in the tunnel but would add to costs of this alternative and would be in addition to any air filtration improvements needed. These emergency operation standards have the effect of requiring the incorporation of tunnel ventilation features as well.

1.4 Elevated Tunnel Evaluation

1.4.1 Air Treatment Requirements

An air cleaning or treatment system in an elevated tunnel would likely be an electrostatic precipitator (ESP), as such systems are commonly used in tunnels and have greater flexibility in the location they can be placed. For instance, an ESP could be installed above the roadway in order to limit the horizontal footprint of the structure. Electrostatic precipitators are commonly used in tunnel systems as they have a capacity to handle large gas volumes (approximately 4

[1] Wind monitoring and modeling may also be necessary to determine the potential impact of prevailing winds relative to proposed tunnel portals.

million ft^3 per minute), high collection efficiencies (90 – 99+%), even for small particle sizes, and require relatively small amounts of energy to run (Wark, Warner, Davis, 1998).[2]

If the tunnel extends beyond the areas of potentially high PM_{10}, an air cleaning system may not be required specifically for the management of PM_{10}, as the tunnel could adequately shield the roadway surface. An analysis of local wind patterns would be necessary to determine if the tunnel's orientation would adequately shield the roadway surface. Even if air treatment systems were determined unnecessary, air ventilation systems (such as shown in Exhibit 2) would be needed to ensure a method for air dilution for emergency operations.

1.4.2 Inlet and Outlet Air Volume Requirements (Ventilation)

Based on the discussion in Section 1.3.3, it is assumed the elevated tunnel will require ventilation with outside air and that National Ambient Air Quality Standards (NAAQS) for all criteria pollutants will be met inside the tunnel. No modeling was conducted to determine the need for ventilation to manage vehicle emissions in the tunnel. However, with a projection of 28,650 vehicles per day in this segment of Highway 53 over the next twenty years, traffic levels are substantially below standard thresholds for emissions concerns. If modeling were performed, calculations for tunnel ventilation would be based upon the US EPA's MOVES software program methodology. Factors impacting tunnel ventilation include traffic density, speed, vehicle type, and nitrogen oxides (NO_X) and carbon monoxide (CO) dilution requirements.

Part of the assessment for fire protection in a tunnel is the determination of a "design fire." This is based on a variety of factors, most notably the types of vehicles that may pass through a tunnel and the potential for flammable materials within the tunnel. Tunnel characteristics and the fire protection standards will dictate that a ventilation system be put in place. However, there are some measures that when taken would help to limit the expense of the system. For instance, prohibiting the passage of trucks containing hazardous materials or requiring a police escort through the tunnel would help to reduce the design requirements for fire suppression.

1.4.3 Maintenance of an Air Mitigation System

Tunnel and system maintenance could include regular tests of fans, emergency call boxes, lighting systems, fire monitoring and protection systems, and any required air filtration and cleaning equipment. Air filtration and cleaning equipment would need to be inspected, calibrated, and cleaned on a regular basis to ensure their proper removal of air pollutants. Given the length of the potential elevated tunnel, there is a high standard given for maintenance of lighting within the tunnel. These maintenance tasks would be in addition to any roadway or tunnel structure maintenance required by MnDOT.

The expected life cycle for air handling and filtration equipment is approximately 25-30 years. While replacement costs may not match the initial costs for purchase and installation, substantial replacement of air equipment would be expected at costs similar to initial installation costs.

1.4.4 Cost Analysis

A cost analysis has been prepared that covers both capital and operating and maintenance costs for tunnel Option 1 and 2. The scope of the cost analysis was limited to the direct and indirect capital investments and the annual operations and maintenance (O&M) costs of ESP air filtration system and emergency fire protection air ventilation fans. Other aspects of the proposed M-1

[2] Fabric filters are another option to treat large volumes of air (approximately 5 million ft^3 per minute) and collection efficiencies can exceed 99% over a broad range of particle sizes(Wark, Warner, Davis, 1998). However, project footprint considerations for this Highway 53 project could prohibit the installation of large baghouses given the desire to limit the horizontal footprint.

route such as the physical tunnel structure, earthwork, drainage, lighting, signage and signalling, construction costs, and utilities were not considered within the scope of this cost analysis.

1.4.4.1 ESP System Cost

As discussed in Section 1.4.1, ESP systems are routinely employed as air quality mitigation systems in tunnels. Most ESP systems installed in tunnels consist of small modular units versus large industrial ESPs installed at power plants or manufacturing facilities. The US EPA's *Air Pollution Training Institutes Electrostatic Precipitator Plan Review* document gives costing guidance for the purchase and O&M cost for such small modular ESP systems. As discussed previously, an ESP was not considered for the tunnel spanning the entire permit-to-mine area (Option 1). The cost analysis for the ESP system therefore only covers the short tunnel span, Option 2.

The total capital cost of the ESP system is a function of the volume of air handled by the system. The tunnel volume was calculated using the dimensions stated in Table 1. The capital cost includes the direct purchase cost of the ESP system and associated auxiliary equipment, installation costs, as well as indirect costs associated with engineering and construction field expenses. The total capital investment for an ESP system for tunnel Option 2 was estimated at approximately $662,000. Annual O&M costs included regular annual maintenance, electricity costs, and recovered dust disposal and were estimated to be approximately $4,800. Indirect annual costs (capital recovery, property taxes, insurance, administrative costs, and overhead) were not considered for this cost analysis.

Detailed calculations, assumptions, and associated references used in the cost analysis are included in Appendix D.

1.4.4.2 Emergency Ventilation Cost

As discussed in Section 1.3.3.3, emergency ventilation systems would be required for both tunnel Option 1 and 2 under FHPA Standard 502. The fans used for emergency ventilation are large axial turbo fans mounted at the top of the tunnel structure. The fans and their associated electrical systems are required to meet certain performance standards during fire events. As a result of their robust design, these fans, their associated equipment, and their installation are expensive compared to the air quality control equipment. A cost analysis was performed for both tunnel Option 1 and 2.

The total capital cost of the emergency ventilation system is a function of the number of fans to be installed in each tunnel. The capital cost includes the direct purchase cost of the fans and associated auxiliary equipment, installation costs, as well as indirect costs associated with engineering and construction field expenses. Fans are typically installed in groups of two and are required to be spaced out along the length of the tunnel as a function of the fan diameter. Option 1 would require approximately 48 fans; whereas, the shorter Option 2 tunnel would require approximately 24 fans. The direct purchase cost of the fans are a fraction of total direct cost as the installation of the associated electrical systems can be one to two times as expensive as the fans themselves. As a result of the substantial installation and design requirements for the fans, the total capital investment for the ventilation system for tunnel Option 1 and 2 were estimated to be $28,000,000 and $14,000,000 dollars, respectively. Annual O&M costs included regular annual maintenance, and electricity costs for tunnel Option 1 and 2 and were estimated to be approximately $55,000 and $28,000, respectively. Indirect annual costs (capital recovery, property taxes, insurance, administrative costs, and overhead) were not considered for this cost analysis.

Detailed calculations, assumptions, and associated references used in the cost analysis are included in Appendix C and D.

1.5 Summary

While the scenario of building an elevated tunnel across an operating mine is unique and with limited applicable case examples to draw from, the technology exists to protect the roadway from PM_{10} levels that exceed the NAAQS standard. This memo does not attempt to predict or identify an expected response from the MPCA or US EPA in regard to the applicability of this mitigation measure to the air quality permit held by Cliffs Natural Resources at United Taconite.

Due to the length of the elevated tunnel considered in Option 1 and 2, fire protection standards become a driving factor in the determination of needed air ventilation and filtration equipment. Table 2 below provides a comparison of the two tunnel lengths, Option 1 and 2, and summarizes the key issues described in this memo.

According to the cost analysis performed for tunnel Option 1 and 2, the reduced cost associated with not having an ESP system in the longer Option 1 tunnel is more than offset by the substantial costs associated with emergency ventilation fans required in both tunnel lengths. In discussions with tunnel ventilation experts, it has been determined that route M-1 is technically feasible and could adequately protect the roadway from elevated PM_{10} levels through the application of proper air handling or filtration equipment; however, there are substantial upfront and ongoing O&M costs associated with achieving this result.

References

Wark, Warner, and Davis. *Air Pollution: It's Origin and Control*, Third Edition, 1998.

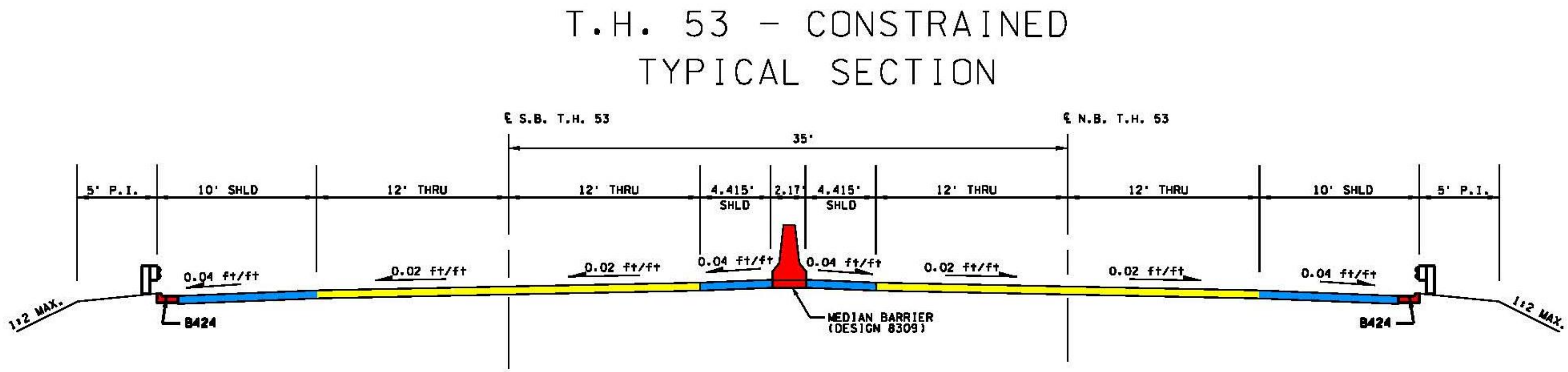
Figure 1 photo. http://www.fhwa.dot.gov/bridge/tunnel/pubs/nhi09010/02a.cfm

TABLE 2. COMPARISON OF TUNNEL LENGTH FEASIBILITY, REQUIREMENTS, AND COSTS

	Tunnel Length Categories for Comparison*	
	Option 1 – FHPA Category D **Long length elevated tunnel** **(greater than 3,280 feet)**	**Option 2 – Category C** **Medium length elevated tunnel** **(1,000 to 3,280 feet)**
Air treatment requirements	Combination of elevated tunnel acting as a barrier and the clean source air at ends of tunnel (portals) eliminates the need for treatment system.	ESP system installation likely
Fire safety requirements	The most strict fire protection requirements apply. Restrictions on vehicles allowed in tunnel can help minimize the most extensive standards.	Still restrictive fire protection requirements, with little difference compared to Category D.
Permitting feasibility/risks	Less difficult permitting application with clean air source at tunnel portals	More challenging permit application process with surrounding air at portals not compliant with NAAQS
Potential cost	Total Fan Capital Cost: $28 million Total Fan Annual Cost: $55,000	Total Fan Capital Cost: $14 million Total Fan Annual Cost: $28,000 Total ESP Capital Cost: $773,000 Total ESP Annual Cost: $7,000

*Categories are based upon the National Fire Protection Association (NFPA) Standard for Road Tunnel Length (NFPA 502 (2011) 7.2). As described in the tech memo, fire protection standards drive many of the treatment and ventilation system requirements for tunnels of various lengths.

Attachment A – Typical Cross Section for the M-1 Alignment



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Attachment B – National Fire Protection Association (NFPA) Standard 502 Tunnel Length Requirements

NFPA 502 (2011) 7.2 Road Tunnel Length. For the purpose of this standard, tunnel length shall dictate the minimum fire protection requirements, as shown in Table 7.2 and as follows:

(1) Category X - Where the tunnel length is less than 90 m (300 ft), the provisions of this standard shall not apply.

(2) Category A - Where tunnel length is 90 m (300 ft) or greater, standpipe systems and traffic control systems shall be installed in accordance with the requirements of Chapter 9 and Section 7.6, respectively.

(3) Category B - Where tunnel length equals or exceeds 240 m (800 ft) and where the maximum distance from any point within the tunnel to a point of safety exceeds 120 m (400 ft), all provisions of this standard shall apply.

(4) Category C - Where tunnel length equals or exceeds 300 m (1000 ft) all provisions of this standard shall apply unless noted otherwise in this document.

(5) Category D - Where the tunnel length equals or exceeds 1000 m (3280 ft), all provisions of this standard shall apply.

Table A.7.2 *Continued*

Fire Protection Systems	NFPA 502 Sections	X [See 7.2(1).]	A [See 7.2(2).]	B [See 7.2(3).]	C [See 7.2(4).]	D [See 7.2(5).]
Traffic Control						
Stop traffic approaching tunnel portal	7.6.1	MR	MR	MR	MR	MR
Stop traffic from entering tunnel's direct approaches	7.6.2	—	—	MR	MR	MR
Fire Protection						
Fire apparatus[d]	7.7	—	—	—	—	—
Fire standpipe	7.8/10.1	—	MR	MR	MR	MR
Water supply	7.8/10.2	—	MR	MR	MR	MR
Fire department connections	10.3	—	MR	MR	MR	MR
Hose connections	10.4	—	MR	MR	MR	MR
Fire pumps[e]	10.5	—	CMR	CMR	CMR	CMR
Portable fire extinguishers	7.9	—	—	MR	MR	MR
Fixed water-based fire-fighting systems[f]	7.10/9.0	—	—	—	CMR	CMR
Emergency ventilation system[g]	7.11/11.0	—	—	CMR	CMR	MR
Tunnel drainage system[h]	7.12	—	CMR	MR	MR	MR
Hydrocarbon detection[h]	7.12.7	—	CMR	MR	MR	MR
Flammable and combustible environmental hazards[i]	7.15	—	—	CMR	CMR	CMR
Means of Egress						
Emergency egress	7.16.1.1	—	—	MR	MR	MR
Exit identification	7.16.1.2	—	—	MR	MR	MR
Tenable environment	7.16.2	—	—	MR	MR	MR
Walking surface	7.16.4	—	—	MR	MR	MR
Emergency exit doors	7.16.5	—	—	MR	MR	MR
Emergency exits (includes cross-passageways)[j]	7.16.6	—	—	MR	MR	MR
Electrical Systems[k]						
General	12.1	—	CMR	MR	MR	MR
Emergency power	12.4	—	CMR	MR	MR	MR
Emergency lighting	12.6	—	CMR	MR	MR	MR
Exit signs	12.6.8	—	CMR	MR	MR	MR
Security plan	12.7	—	CMR	MR	MR	MR
Emergency Response Plan						
Emergency response plan	13.3	MR	MR	MR	MR	MR

(Road Tunnel Categories: X, A, B, C, D)

MR: Mandatory requirement (3.3.37). CMR: Conditionally mandatory requirement (3.3.37.1).

Note: The purpose of Table A.7.2 is to provide guidance in locating minimum road tunnel fire protection requirements contained within this standard. If there is any conflict between the requirements defined in the standard text and this table, the standard text must always govern.

[a]Determination of requirements in accordance with Section 7.3.

[b]Determination of requirements in accordance with Section 7.4.

[c]Determination of requirements in accordance with Sections 4.5 and 7.5.

[d]Not mandatory to be at tunnel; however, they must be near to minimize response time.

[e]If required, must follow Section 10.5.

[f]If installed, must follow Section 7.10 and Chapter 9.

[g]Section 11.1 allows engineering analysis to determine requirements.

[h]If required, must follow Section 7.12.

[i]Determination of requirements in accordance with 7.16.2.

[j]Emergency exit spacing must be supported by an egress analysis in accordance with 7.16.6.

[k]If required, must follow Chapter 12.

Attachment C – Tunnel Option 1 Cost Analysis

Option 1

Tunnel Dimensions

Length	6,100	feet
	1,860	m
Width	74	feet
Height	17.3	feet
Volume	7,824,267	cubic feet

1.0 ESP Capital Cost

An ESP system is not considered for Option 1 as the tunnel portals are outside the area of elevated PM10 concentrations

2.0 Turbo Fan Capital Cost

Fan Group Spacing	150	m
# of fans per group	2	
# of tunnel bores	2	
# fans required	48	
Fan unit cost	$110,000	
Total fan purchase cost	$5,280,000	

Note:

- Fan spacing: at least 100 fan diameters or 10 tunnel hydraulic diameters are needed between fan groups and the portals. [(1,860 m / 150 m) - 1] * 2 fans/group * 2 tunnel bores = 48 fans
- Fan unit cost is based on assumed 3' diameter reversible fire-hardened turbo fan

Annual Operating Time 100 hr/yr (testing/maintenance)

Cost Item	Cost	Factor
Direct Costs		
Purchased equipment costs		
Turbo fan + auxiliary equipment	$5,280,000	48 fans @ $110000 /each
Instrumentation	$ -	(Included in fan cost)
Sales taxes	$ -	(Included in fan cost)
Freight	$ 264,000.00	= 0.05 A
Purchased equipment costs, PEC	$ 5,544,000.00	B = 1.05 A
Direct installation costs		
Foundations and supports	$ 221,760.00	= 0.04 B
Handling and erection	$ 2,772,000.00	= 0.50 B
Electrical	$ 11,088,000.00	= 2 B
Piping	$ 55,440.00	= 0.01 B
Controls and communications	$ 5,544,000.00	= 1 B
Insulation for ductwork	$ -	No ductwork w/ vent fans
Painting	$ -	No painting required
Direct installation costs	$ 19,681,200.00	= 3.55 B
Total Direct Costs, DC	$ 25,225,200.00	

Indirect Costs			
Engineering	$	1,108,800.00	= 0.20 B
Construction and field expenses	$	1,108,800.00	= 0.20 B
Contractor fees	$	554,400.00	= 0.10 B
Start-up	$	55,440.00	= 0.01 B
Performance test	$	55,440.00	= 0.01 B
Model study	$	110,880.00	= 0.02 B
Contingencies	$	166,320.00	= 0.03 B
Total Indirect Costs, IC	$	3,160,080.00	= 0.57 B
Total Capital Investment = DC + IC	$	28,385,280.00	

Notes:
- Cost structure adapted from Capital cost table of factors source: EPA Air Pollution Control Cost Manual, Sixth Edition, EPA/452/B-02-001, January, 2002. Table 3.16: Capital Cost Factors for ESPs
- Purchase cost source: Fan unit cost is based on assumed 3' diameter reversible fire-hardened turbo fan

- Substantial electrical costs are due to many factors: voltage drop in long tunnels; motor starters and switchgear requirements as fans must be up to full speed in 60 seconds; no exposed wiring; conduit cannot be surface mounted; electrical must be buried or run in duct banks. Electrical is typically at least 1x - 2x cost of fans.

- Substantial control and communication cost is due to many factors: must have a fireman's control panel at the portals; no wiring or conduit may be exposed; need approximately 9 temperature/status monitoring points per fan.

2.1 Turbo Fan Maintenance Costs

Cost Item		Cost	Note
Purchased equipment costs, PEC	$	5,544,000.00	
Annual Maintenance cost	$	55,440.00	1% of PEC

Notes:
- EPA Air Pollution Control Cost Manual: Annual maintenance materials are estimated as 1 percent of the purchase cost. (Adapted from ESP maintenance cost)

2.2 Turbo Fan Electricity Costs

Cost Item		Cost	Note
Power consumption		30	kw
Electricity demand		3,000	kWh/yr
Average MN electricity rate	$	0.0823	$/kWh
Annual electricity cost	$	246.90	

Note:
- WITT & SOHN Tunnel Ventilation Brochure: voltage requirement for a 1,000 mm diameter reversible turbo fan

- Electricity rate: US Energy Information Administration, http://www.eia.gov/electricity/data.cfm#sales. Northern States Power Co. (MN) average retail price for Transportation sector, 2011.

2.3 Turbo Fan Indirect Annual Costs

Indirect annual costs (capital recovery, property taxes, insurance, administrative costs, and overhead) were not considered for this cost analysis.

2.4 Turbo Fan Total Annual Costs

Cost Item		Cost	Percent of Annual Total
Maintenance Costs	$	55,440.00	99.6%
Electricity Costs	$	246.90	0.4%
Total Annual Costs	$	55,686.90	100.0%

3.0 ESP and Turbo Fan Total Costs

Cost Item		Cost
ESP Total Capital Cost	$	-
ESP Total Annual Cost	$	-
Turbo Fan Total Capital Cost	$	28,385,280.00
Turbo Fan Total Annual Cost	$	55,686.90

Attachment D – Tunnel Option 2 Cost Analysis

Option 2

Tunnel Dimensions

Length	3,000	feet
	915	m
Width	74	feet
Height	17.3	feet
Volume	3,848,000	cubic feet

1.0 ESP Capital Cost

Operational Parameters

Tunnel Volume Turnover Time	1.00	hr
Air Flow Rate	64,133	acfm
Annual Operating Time	8,592	hr/yr (51 weeks/yr - 1 week downtime)

Miscellaneous Parameters

CPI Adjustment Factor	2.06	(2013 purchasing power from 1987 dollars)

Cost Item	Cost	Factor
Direct Costs		
Purchased equipment costs		
ESP + auxiliary equipment	$ 295,781.74	A = -255,610 + 36,065 ln (acfm)
Instrumentation	$ -	(Incl. in ESP purchase cost)
Sales taxes	$ -	(Incl. in ESP purchase cost)
Freight	$ -	(Incl. in ESP purchase cost)
Purchased equipment costs, PEC	$ 295,781.74	B = A
Direct installation costs		
Foundations and supports	$ 11,831.27	= 0.04 B
Handling and erection	$ 147,890.87	= 0.50 B
Electrical	$ 23,662.54	= 0.08 B
Piping	$ 2,957.82	= 0.01 B
Insulation for ductwork	$ 5,915.63	= 0.02 B
Painting	$ 5,915.63	= 0.02 B
Direct installation costs	$ 198,173.77	= 0.67 B
Total Direct Costs, DC	$ 493,955.51	= 1.67 B
Indirect Costs		
Engineering	$ 59,156.35	= 0.20 B
Construction and field expenses	$ 59,156.35	= 0.20 B
Contractor fees	$ 29,578.17	= 0.10 B
Start-up	$ 2,957.82	= 0.01 B
Performance test	$ 2,957.82	= 0.01 B
Model study	$ 5,915.63	= 0.02 B
Contingencies	$ 8,873.45	= 0.03 B
Total Indirect Costs, IC	$ 168,595.59	= 0.57 B
Total Capital Investment = DC + IC	$ 662,551.10	= 2.24 B

Notes:
- Capital cost table of factors source: EPA Air Pollution Control Cost Manual, Sixth Edition, EPA/452/B-02-001, January, 2002. Table 3.16: Capital Cost Factors for ESPs
- Purchase cost source: EPA's Air Pollution Training Institutes Electrostatic Precipitator Plan Review, Lesson 4, ESP Design Review, 2.0-2, 1998. Figure 4-5. Purchase costs for two-stage, two-cell precipitators

- Purchase cost of ESP system adjusted from second quarter 1987 dollars using US Dept. of Labor Consumer Price Index Calculator, http://data.bls.gov/cgi-bin/cpicalc.pl
- The total purchase cost of an ESP system is the sum of the costs of the ESP, options, auxiliary equipment, instruments and controls, taxes, and freight.
- For two stage precipitators, total direct installation costs are more nearly 0.20 to 0.25 times PEC but are kept at 0.67 times PEC due to higher than expected installation costs due to constrained installation area as a result of locating ESP equipment on top of the proposed route M-1.

1.1 ESP Maintenance Costs

Cost Item	Cost	Note
Purchased equipment costs, PEC	$ 295,781.74	
Annual Maintenance cost	$ 2,957.82	1% of PEC

Notes:
- EPA Air Pollution Control Cost Manual: "Based on an analysis of vendor information, annual maintenance materials are estimated as 1 percent of the flange-to-flange precipitator purchase cost"

1.2 ESP Electricity Costs

Cost Item	Cost	Note
Power consumption	40	W/1,000 acfm
Electricity demand	22,041	kWh/yr
Average MN electricity rate	$ 0.0823	$/kWh
Annual electricity cost	$ 1,814.00	

Note:
- EPA Air Pollution Control Cost Manual: For two-stage precipitators, power consumption ranges from 25 to 100 W/kacfm, with 40 W/kacfm being typical.
- Electricity rate: US Energy Information Administration, http://www.eia.gov/electricity/data.cfm#sales. Northern States Power Co. (MN) average retail price for Transportation sector, 2011.

1.3 ESP Dust Disposal Costs

Cost Item	Cost		Note
Dust disposal	$	51.50	$/ton dust removed
Inlet PM_{10} Loading		200	$\mu g/m^3$
ESP Removal efficiency		90%	
Air flow rate		936,601,020	m^3/yr
Annual Dust Removal		0.19	tons/yr
Dust removal cost	$	9.57	

Note:
- EPA Air Pollution Control Cost Manual: Costs may typically run $20/ton or $30/ton for nonhazardous wastes exclusive of transportation (corrected to 2013 dollars in calculation)
- Transportation costs were not assumed. The disposal costs are highly site-specific and depend on transportation distance to the landfill, handling rates, and disposal unloading (tipping) fees.

1.4 ESP Indirect Annual Costs

Indirect annual costs (capital recovery, property taxes, insurance, administrative costs, and overhead) were not considered for this cost analysis.

1.5 ESP Total Annual Costs

Cost Item	Cost		Percent of Annual Total
Maintenance Costs	$	2,957.82	61.9%
Electricity Costs	$	1,814.00	37.9%
Dust Disposal Costs	$	9.57	0.2%
Total Annual Costs	$	4,781.39	100.0%

2.0 Turbo Fan Capital Cost

Fan Group Spacing	150	m
# of fans per group	2	
# of tunnel bores	2	
# fans required	24	
Fan unit cost	$110,000	
Total fan purchase cost	$2,640,000	

Note:
- Fan spacing: at least 100 fan diameters or 10 tunnel hydraulic diameters are needed between fan groups and the portals. [(1,860 m / 150 m) - 1] * 2 fans/group * 2 tunnel bores = 48 fans
- Fan unit cost is based on assumed 3' diameter reversible fire-hardened turbo fan

Annual Operating Time	100	hr/yr (testing/maintenance)

Cost Item		Cost	Factor
Direct Costs			
Purchased equipment costs			
Turbo fan + auxiliary equipment		$2,640,000	24 fans @ $110000 /each
Instrumentation	$	-	(Included in fan cost)
Sales taxes	$	-	(Included in fan cost)
Freight	$	132,000.00	= 0.05 A
Purchased equipment costs, PEC	$	2,772,000.00	B = 1.05 A
Direct installation costs			
Foundations and supports	$	110,880.00	= 0.04 B
Handling and erection	$	1,386,000.00	= 0.50 B
Electrical	$	5,544,000.00	= 2 B
Piping	$	27,720.00	= 0.01 B
Controls and communications	$	2,772,000.00	= 1 B
Insulation for ductwork	$	-	No ductwork w/ vent fans
Painting	$	-	No painting required
Direct installation costs	$	9,840,600.00	= 3.55 B
Total Direct Costs, DC	$	12,612,600.00	
Indirect Costs			
Engineering	$	554,400.00	= 0.20 B
Construction and field expenses	$	554,400.00	= 0.20 B
Contractor fees	$	277,200.00	= 0.10 B
Start-up	$	27,720.00	= 0.01 B
Performance test	$	27,720.00	= 0.01 B
Model study	$	55,440.00	= 0.02 B
Contingencies	$	83,160.00	= 0.03 B
Total Indirect Costs, IC	$	1,580,040.00	= 0.57 B
Total Capital Investment = DC + IC	$	14,192,640.00	

Notes:

- Cost structure adapted from Capital cost table of factors source: EPA Air Pollution Control Cost Manual, Sixth Edition, EPA/452/B-02-001, January, 2002. Table 3.16: Capital Cost Factors for ESPs
- Purchase cost source: Fan unit cost is based on assumed 3' diameter reversible fire-hardened turbo fan

- Substantial electrical costs are due to many factors: voltage drop in long tunnels; motor starters and switchgear requirements as fans must be up to full speed in 60 seconds; no exposed wiring; conduit cannot be surface mounted; electrical must be buried or run in duct banks. Electrical is typically at least 1x - 2x cost of fans.

- Substantial control and communication cost is due to many factors: must have a fireman's control panel at the portals; no wiring or conduit may be exposed; need approximately 9 temperature/status monitoring points per fan.

2.1 Turbo Fan Maintenance Costs

Cost Item	Cost	Note
Purchased equipment costs, PEC	$ 2,772,000.00	
Annual Maintenance cost	$ 27,720.00	1% of PEC

Notes:
- EPA Air Pollution Control Cost Manual: Annual maintenance materials are estimated as 1 percent of the purchase cost. (Adapted from ESP maintenance cost)

2.2 Turbo Fan Electricity Costs

Cost Item	Cost	Note
Power consumption	30	kw
Electricity demand	3,000	kWh/yr
Average MN electricity rate	$ 0.0823	$/kWh
Annual electricity cost	$ 246.90	

Note:
- WITT & SOHN Tunnel Ventilation Brochure: voltage requirement for a 1,000 mm diameter reversible turbo fan

- Electricity rate: US Energy Information Administration, http://www.eia.gov/electricity/data.cfm#sales. Northern States Power Co. (MN) average retail price for Transportation sector, 2011.

2.3 Turbo Fan Indirect Annual Costs

Indirect annual costs (capital recovery, property taxes, insurance, administrative costs, and overhead) were not considered for this cost analysis.

2.4 Turbo Fan Total Annual Costs

Cost Item	Cost	Percent of Annual Total
Maintenance Costs	$ 27,720.00	99.1%
Electricity Costs	$ 246.90	0.9%
Total Annual Costs	$ 27,966.90	100.0%

3.0 ESP and Turbo Fan Total Costs

Cost Item	Cost
ESP Total Capital Cost	$ 662,551.10
ESP Total Annual Cost	$ 4,781.39
Turbo Fan Total Capital Cost	$ 14,192,640.00
Turbo Fan Total Annual Cost	$ 27,966.90